A Quantitative Study of Cardiac Ventricular Mass in Dogs

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ABSTRACT

This study was undertaken to determine the correlations between heart weight, ventricular weight and body weight in adult dogs. A total of 130 dogs was selected for the study after necropsy and histological examination. The body weights (BW) were obtained and a standardized dissection technique was used to obtain the total heart weight (HW), total ventricular mass (VW), right ventricular mass (RvW) and the left ventricular plus the interventricular septum mass (Lv+SW). A strong and significant correlation was found between all variables (BW, HW, VW, Lv+SW and RvW). The following ratios were calculated: HW/BW, RvW/BW, Lv+SW/BW, RvW/VW, Lv+SW/VW, RvW/HW, Lv+SW/HW and Lv+SW/RvW. No sex effect was observed on any ratios. A straight linear relationship was observed between HW and Lv+SW or RvW and between Lv+SW and RvW. The ratios Lv+SW/HW, RvW/HW and Lv+SW/RvW could then be used to predict a normal value of Lv+SW or RvW from a known HW value, or a normal value of Lv+SW from a known RvW value. The relations between BW and HW, Lv+SW or RvW were best described by second order equations. Such equations should be utilized to predict a normal value of HW, Lv+SW or RvW from a known BW value.

RÉSUMÉ

Cette étude consistait à déterminer, chez des chiens adultes normaux, les corrélations entre le poids corporel, le poids du cœur et le poids des ventricules. Suite à un examen post-mortem uniforme et à un examen histologique, 130 chiens furent admis dans l'étude. Les poids corporels (BW) furent notés et une technique standardisée de dissection fut utilisée afin d'obtenir le poids total du cœur (HW), le poids ventriculaire total (VW), le poids du ventricule gauche plus le septum interventriculaire (Lv + SW) et le poids du ventricule droit (RvW). Une très forte corrélation fut observée entre toutes les variables (BW, HW, VW, Lv + SW, RvW). Les rapports suivants furent calculés : HW/BW, Lv + SW/BW, RvW/BW, Lv + SW/VW, RvW/VW, Lv + SW/HW, RvW/HW et Lv + SW/RvW. Aucun de ces rapports n'a présenté d'effet relié au sexe. Une relation linéaire simple fut observée entre HW et Lv + SW ou RVW et entre Lv + SW et RvW. Les rapports Lv + SW/HW, RvW/HW et Lv + SW/RvW peuvent donc être utilisés pour estimer soit une valeur normale de Lv + SW ou de RvW à partir du poids total du cœur ou une valeur normale de Lv + SW à partir du poids du ventricule droit. Les relations entre BW et HW, Lv + SW ou RvW correspondaient à des équations de type quadratique. Ces équations devraient être utilisées pour estimer une valeur normale de HW, Lv + SW ou RvW à partir du poids corporel.

INTRODUCTION

Cardiac ventricular hypertrophy is characterized by an increase in the mass of one or both ventricles. It is difficult to detect when it is mild or accompanied by dilation of the chamber. Estimation of cardiac hypertrophy at necropsy is usually attempted by one or a combination of the following methods: observation of the cardiac configuration (1, 2), ventricular wall thickness measurements (3–5), weighing of the heart in relation to the body weight (HW/BW) (6-9) or weighing of the ventricles, each in relation to its counterpart, and to the heart or the body weight (10–12).

Careful observation of the heart's configuration can give an indication of the presence of ventricular hypertrophy but will not necessarily show its presence when it is mild, nor quantify its severity. Detecting ventricular hypertrophy by using only ventricular wall thickness measurements is not a sensitive method (12–15). Wall thickness depends on the muscle bulk and the cavity volume (2). Thus, it can be profoundly modified by factors such as chamber dilation, site of measurements, and postmortem rigor. The heart weight includes a portion of extra-myocardial tissues, and obesity, emaciation or physical activity are

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Submitted February 18, 1991.

likely to modify both heart and body weights (7, 16). Thus, an increase in the HW/BW ratio might not reflect a true variation in myocardial mass (17). Furthermore, HW/BW cannot differentiate between right, left or bilateral ventricular hypertrophy (18). Different techniques were utilized to isolate the ventricular mass (10–12, 18). However, the modified Fulton's technique has become widely used in studies of left or right ventricular hypertrophy. Its main advantage is that the septum is considered together with the left ventricle, which simplifies the dissection technique without loss of precision (12, 16).

Many studies of cardiac hypertrophy in humans and animals have dealt with heart and ventricular weights and put forward certain ratios as criteria for cardiac hypertrophy (2, 12, 16, 18). Nevertheless, to determine precisely the presence of ventricular hypertrophy using cardiac weights and ratios, it is imperative to establish sound normal values. However, few normal values have been published, especially in animals (8, 11, 18–21). Moreover, the criteria of normality applied in some of those investigations are not clearly stated or are limited.

The objectives of this study were to determine correlations between heart, ventricular, and body weights using a large number of carefully selected adult dogs, to verify the possible influence of either sex or body weight on these correlations, and to establish ratios and their range for a normal population.

MATERIALS AND METHODS

Dogs used in this study were selected from cases of accidental or natural death and from elective euthanasia submissions to the diagnostic laboratory of the Faculté de Médecine vétérinaire de l'Université de Montréal. To be admissible, they had to be from one to nine years old and not obese or emaciated; working and racing dogs were also excluded from this investigation. Dogs with available medical history had to be free of previous cardiovascular diseases.

In order to select animals with normal hearts, a thorough and standardized postmortem examination was conducted on all dogs. The body weight (BW) was determined to the nearest 0.2 kg and all organs were examined for abnormal findings. For each dog, the right eye was fixed in Bouin's solution and the pituitary, thyroid, parathyroid and adrenal glands, sections of heart, lungs, liver, spleen, kidneys, and other tissues if necessary were fixed in 10% neutral buffered formalin and embedded in paraffin. Sections were stained with hematoxylin-phloxin-saffron and the microscopical examination was to identify possible lesions that could result in cardiac abnormalities. Dogs with neoplasms or significant chronic lesions, especially lesions of the lungs, kidneys, thyroid and adrenal glands, were discarded. The eye was removed to detect various lesions of the retina that can be early manifestations of systemic hypertension (22). The hearts of the dogs selected had to be free of congenital anomalies, hypertrophy or dilation, or chronic valvular disease of grade II, III or IV (23) and of any acquired lesions namely endocardial jet lesions, focal myocardial fibrosis or necrosis and coronary arteriosclerosis. Dogs had also to be free of infection with adult *Dirofilaria immitis*.

A standardized dissection technique derived from the modified Fulton's technique (12) was used to dissect and weigh the total heart, right ventricle, and left ventricle attached to the interventricular septum.

After separation of the lungs from the heart, the pericardium was incised and removed, and the epicardium was inspected. The great vessels were transected at the base of the heart just beneath the *ligamentum arteriosum*. Then, the right atrium, right ventricle, left atrium and left ventricle were incised to allow the blood clots to be washed away. The left ventricular free wall was cut slightly laterally to the left atrium in the base-apex axis so the incision passed just between the two papillary muscles. The heart was then weighed. Using sharp scissors adjacent to the line of septal reflection and progressing through the right atrial opening, the right ventricular free wall was separated from the septum caudally from base to apex and ventrally from apex to base ending in the pulmonary trunk. The papillary muscles and *trabeculae carneae* protruding from the septum into the right ventricular chamber were cut off and later weighed with the right ventricle. The incision proceeded into the left ventricular wall and was carried on towards the base. The left atrioventricular valve was examined, then slit, so the aortic valve could be inspected. After the *chordae tendinae* were cut off at their junction with the papillary muscles, the atrium was dissected from the left ventricle and interventricular septum following the *anuli fibrosi cordis* of the atrioventricular and aortic valve which were then removed. The right ventricular wall was separated from the atrium in a similar fashion, taking care to remove the septal cusp of the right atrioventricular valve. Epicardial fat was dissected from both parts of the heart and discarded.

Total heart weight (HW), right ventricular weight (RvW), and left ventricular plus septum weight (Lv + SW) were determined. Total ventricular weight (VW) was obtained by the addition of RvW and Lv + SW. The following ratios were calculated: HW/BW, RvW/BW, Lv + SW/BW, RvW/VW, Lv + SW/VW, RvW/HW, Lv + SW/HW and Lv + SW/RvW. Regression analysis and Pearson's correlation coefficients were used to obtain a regression equation and to measure the association between various weights used in the different ratios. Variance and contrast analysis were utilized to measure the dispersion of the various weights used in the different ratios and to detect significant difference in each ratio between groups of body weights. A p value ≤ 0.05 was chosen for statistical significance. The results were computed and analyzed with the Statistical Analysis System (24).

RESULTS

A total of 130 adult dogs, mostly mongrels, was selected for the study after necropsy and histological examination; they were considered to have normal hearts. Of those, 72 were males and 58 were females. The average weight of the dogs was 19.46 ±

10.72 (SD) kg and the weights ranged from 2.7 to 47.8 kg.

Strong and significant correlations were found between BW and HW, Lv + SW, RvW, or VW; between HW and Lv + SW, RvW or VW; between VW and Lv+SW or RvW and between Lv+SW and RvW. The r values were all above 0.92 and the p values, equal to or less than 0.0001. The total ventricular weight (VW) was highly correlated ($r \geq 0.99$) to the heart weight (HW) but was not found to be of any additional value to the use of HW, so the ratios involving VW are not given. The relations between HW and Lv + SW or RvW and between Lv + SW and RvW were characterized graphically by a straight line. However, the relationships between BW and HW, Lv + SW or RvW were found to be best described by second order models with the points forming a stream curving up to the right but flattening out as body weight increased (Fig. 1). Their corresponding regression equations, confidence intervals and R^2 (coefficients of multiple determination) are given in Table I. In an attempt to explain these nonlinear relationships, the study population was separated according to the sex of the dogs, then broken down in three categories of body weights: 15 males and 14 females weighing less than 10 kg, 30 males and 28 females weighing between 10.1 and 25 kg, and 27 males and 16 females with a weight of 25.1 kg or more. Each ratio, between the groups of weights and between sexes was compared. A sex effect was not observed in any ratios, so the data were pooled for subsequent analyses. By contrast analysis, a significant difference ($p \leq 0.05$) in HW/BW was found between all groups of body weights; such a difference, for Lv + SW/BW and RvW/BW, was only present between the 10.1–25 kg and 25 kg and over groups (Table II). For all other ratios, no significant difference between the three groups of body weights was observed. The means ± SD for Lv + SW/HW, RvW/HW and Lv + SW/RvW are reported in Table III.

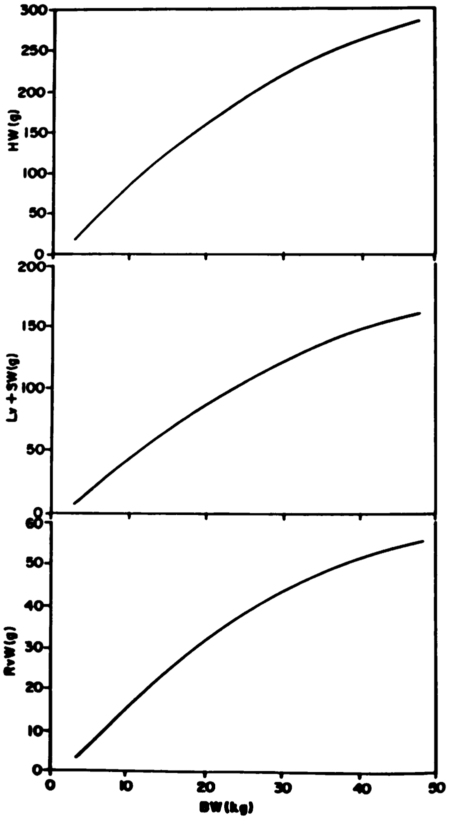

Fig. 1. Variations of heart weight (HW), left ventricular plus septum weight (Lv + SW) and right ventricular weight (RvW) as a function of body weight in 130 normal adult dogs. These relations follow a second order model.

TABLE III. Ratios involving heart weight (HW), left ventricular plus septum weight (Lv + SW), and right ventricular weight (RvW) in 130 normal dogs[a]

Ratios (g/g)	Mean	Standard deviation
Lv+SW/HW	0.54	0.03
RvW/HW	0.19	0.01
Lv+SW/RvW	2.77	0.23

[a]$r \geq 0.98$ and $p \leq 0.0001$

TABLE I. Regression equations involving body weight (BW) and heart weight (HW), left ventricular plus septum weight (Lv + SW) or right ventricular weight (RvW) in 130 normal dogs[a]

Regression equation	R^{2b}	C.I.[c]
$HW = -10.59 + 0.01BW - (8 \times 10^{-8}BW^2)$	0.90	46.72
$Lv + SW = -6.91 + 0.005BW - (4.3 \times 10^{-8}BW^2)$	0.88	29.72
$RvW = -3.03 + 0.002BW - (1.9 \times 10^{-8}BW^2)$	0.88	10.28

[a]All variables are in grams
[b]Coefficient of multiple determination at a p value ≤ 0.001
[c]95% confidence interval for the dependant variables (± g)

TABLE II. Ratios involving body weight (BW) and heart weight (HW), left ventricular plus septum weight (Lv + SW) or right ventricular weight (RvW) in 130 normal dogs grouped according to their body weight (mean ± SD)

Ratios (g/g)	Groups of body weight (kg) 0–10 (n = 29)	10.1–25 (n = 58)	≥ 25.1 (n = 43)
HW/BW%	0.84 ± 0.10[a]	0.79 ± 0.12[b]	0.72 ± 0.11[c]
Lv+SW/BW%	0.46 ± 0.07[a]	0.43 ± 0.08[a]	0.40 ± 0.07[b]
RvW/BW%	0.16 ± 0.02[a]	0.16 ± 0.03[a]	0.14 ± 0.02[b]

[abc]Different superscripts in the same row indicate significant differences at p ≤ 0.05

DISCUSSION

In dogs, the relationship between heart weight and body weight expressed as the HW/BW ratio has been described in several studies; in some, hearts were dissected and various ratios and normal ranges were also reported (6, 8, 9, 11, 18, 19). However, several of these investigations were limited either by the relatively low number of dogs studied, the inadequate range of body weights or the meager criteria of normality used. Normality, in most of the studies, was defined as the absence of gross pulmonary, renal or cardiac lesions. In the present study, a complete and standardized postmortem examination was performed on each dog; criteria to determine normality were based on histological as well as gross observations.

The heart dissection technique previously employed has been faced with the problem of the allocation of the septum weight (10–12, 18). However, as Drechsel (25) pointed out, the right component of the septum is practically negligible, the septum being almost exclusively part of the left ventricle. This observation is in agreement with other studies which have shown that a significant increase in the septal weight will appear only with concomitant left ventricular hypertrophy (12, 26). Furthermore, since the septal surface of the left ventricle is concave and the septal surface of the right ventricle is rather convex, separation of the right ventricle from the septum is much easier and more precise than separation of the left ventricle from the septum (12, 27). The modified Fulton's technique, in which the septum is incorporated with the left ventricle, has been used by many workers and has become the technique of choice (2, 13, 16, 21, 28).

A simple linear relationship was found between HW and Lv + SW or RvW and between Lv + SW and RvW, without any effect of sex or of body weight. In contrast to some previous studies in humans (2, 7, 14, 16, 28) or in dogs (8) which demonstrated a difference in the HW/BW ratio between sexes, results of this study showed that sex, in the dog, did not significantly influence the HW to BW ratio or the other ratios computed. This observation is in agreement with other studies which have shown that the HW/BW ratio in animals did not vary significantly between sexes (6, 19, 29).

The HW/BW ratio has been widely used as a mean of describing the relationship between HW and BW or to predict either the HW from a known BW or a ventricular weight, such as the left ventricular weight, from a known HW/BW value (6, 9, 30). However, there is some agreement among investigators that the HW/BW ratio is not a sensitive means of detecting small variations in ventricular weight and gives at best a crude approximation of the left ventricular weight (7, 8, 13, 14). Furthermore, unlike the earlier findings of some researchers (8, 31) heart weight was not found to vary according to a straight-line model with the body weight. In our study, second order models have best predicted the value of HW, Lv + SW or RvW from a known BW value. This observation is in agreement with previous studies in humans and animals which have shown a similar relationship, either described by a second order or an allometric equation, between HW and BW (29, 32, 33). The kind of graph expressing this relationship can be related to the general growth curve of an organ weight plotted against the body weight (30, 32).

Dogs used in this study were neither obese nor emaciated; however, the general canine population does not always comply with these requirements. Such factors as obesity, physical activity and even the breed have been reported in previous studies to modify the HW/BW ratio (6, 8). Future studies should verify and clearly establish the influence of these factors on the HW/BW and other ratios.

In summary, normal values were established for various ratios of cardiac weights. A straight linear relationship was only encountered between HW and Lv + SW or RvW and between Lv + SW and RvW. Therefore, one can estimate, using those ratios, a normal value of Lv + SW or RvW from a known HW value or a normal value of Lv + SW from a known RvW value. The relationships between BW and HW, Lv + SW or RvW were best described by second order equations. Such equations should be used when predicting a normal value of HW, Lv + SW or RvW from a known BW value. Other studies are needed to ascertain the relevance of the various ratios and regression equations computed in this study in determining ventricular cardiac hypertrophy in dogs.

ACKNOWLEDGMENTS

The authors are grateful to G. Dumas and Dr. S. D'Allaire for their assistance with data analysis.

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